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Publication date:
2015

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):
Andersen, P. B., & Clemmensen, C. (2015). *EV owner smart grid involvement*. Paper presented at Electromobility Challenging Issues, Singapore , Singapore.

EV owner smart grid involvement

Trusting a 3rd party to charge your car

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Introduction

The electric vehicle has properties that highly elevate its value as a resource to the power system. Specifically, the EV is a high-power, fast-response unit with an attached energy storage (battery) and potentially with bi-directional capabilities (V2G). These properties can be used in a number of power and energy services which can support power system operation while lowering cost of EV ownership.

The Danish Nikola project[1] has systematically collected and analyzed such services as part of a "service catalog". The services cover everything from adaptive charging (commonly known as smart charging) to using the vehicle for ancillary services or local grid support.

The EVs qualities as a resource to the power system mean little, however, without the EV owner's ***ability*** and ***willingness*** to participate in such schemes. By ***ability*** is meant whether the vehicle will be connected to the power system (plugged in) for sufficiently long durations in time while following a predictable and recurring pattern. This topic has already been investigated in a number of studies. In [2] it was shown that typical nightly plugins lasted for around 13 hours – of which only four hours were needed for charging. This indicates a high degree of charging flexibility.

The EV owners ***willingness*** to participate in managed charging has been investigated in projects such as the Swedish ELVIIS project [3], the Australian Victoria's smart grid project[4] and the Danish Test-An-EV project[5]. These projects have helped the authors of this paper identify three main factors that influence user participation willingness:

1. **Economic and "feel-good" incentives**
2. **Convenience and ease-of-use**
3. **Transparency, information and sense of control**

It is the hypothesis of the authors that if the users are sufficiently informed and empowered through well-implemented user interface functionalities, they can be made to participate in power and energy services – and thereby trust a 3rd party to manage the charging of their vehicles.

Methodology

To test the above hypothesis, a test interface has been developed. The interface is not meant to represent a functional product – but rather a showcase of functionalities. While an EV interface could include everything from trip planning to pre-heating – the emphasis here is on the functionalities directly relevant for EV service participation. These "enabling" functionalities are as follows:

1. **Charging status and management** What is the charging status right now?
2. **Scheduled charge windows** When is the 3rd party allowed to manage charging?
3. **Spend and earned so far this month** What has the user achieved by participating?
4. **Subscriptions** Which services is the vehicle allowed to participate in?

The above functionalities have been described in a number of user story maps which are meant to identify and support relevant use scenarios. The test interface was then developed using Lean UX which is an iterative methodology designed to quickly develop a minimal viable product.

Analysis of charging patterns

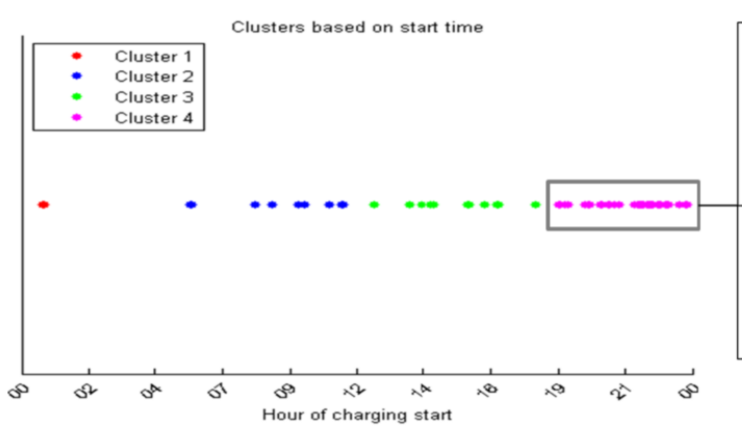
To add to the convenience and ease-of-use to the EV owner, a backend system may analyze the charging patterns of an EV. This analysis can be used to inform the EV owner on which time intervals that the EV would be able to participate in grid services without interfering with driving needs.

Essentially, the vehicle would be able to participate in services during any plug-in session which is sufficiently long, compared to the energy need, so that it grants flexibility for delaying charging in time and which is predictable in nature and recurs according to a certain pattern.

By analyzing historic charging data, two types of information can be obtained:

1. Automatic identifications of recurring charging sessions, based on spatiotemporal data, suitable for service participation.
2. For each charging session determine the expected departure time at which an energy target will have to be meet.

A relevant source for such investigations is the Danish Test-An-EV trails where 198 EVs where driven by a total of 1578 families. All the driving and charging behavior have been recorded and investigated as part of the Nikola project. Figure 1 represents data from a single household with one of the Test-An-EV vehicles. Each dot represents the start of a charging session. A K-means cluster analysis has been applied to the start-times to create a total of four clusters. Each cluster is a group of recorded charging sessions with a similar start-time. The last, right-most, cluster representing plugins between 7 PM and midnight could be classified as "over-night charging". Statistics is shown for this single cluster in the figure below.



Plug in time	
min	19:14:09
mean	21:56:07
max	23:47:45
q25	21:10:26
q75	22:44:15

Duration of plug in	
min	00:21:44
mean	09:59:13
max	18:01:26
q25	08:56:34
q75	11:10:19

Duration of charge	
min	00:09:38
mean	02:42:19
max	07:03:12
q25	01:55:24
q75	03:15:39

Figure 1- K-means cluster analysis on charging session start times (Sigurd R. P. 2014)

By investigating the mean charging and plugin duration, and the variance of the plug in duration (an expression of the predictability of plug-out) it can be assess if a cluster in general is suitable for service participation. The clustering can also be combined with GPS data to identify where the vehicle is connected.

Such investigations as will aid the "scheduling" functionality which will be described in the following section.

Functionalities

Functionality one: Charging status and management

The first functionality is meant to provide an overview of the current plugin session. Besides from informing the user about whether the vehicle is plugged in and charging, the user should also be given information on the expected time at which the vehicle is fully charged. Also, the user should be able to quickly disable any external charging management by switching from "smart" to "Instant charging".

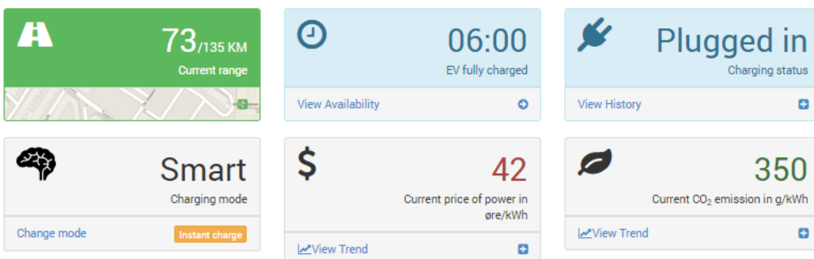


Figure 2- Charging status and management

Functionality two: Scheduled charge windows

The "Scheduled charge windows" functionality is suggested as a way of informing the EV owner about the recurring time windows used for managed charging including contracted deadlines for charging completion. By analyzing the charging behavior, as mentioned in the "Analysis of charging patterns" section, it is possible to suggest new charge windows or to change the existing charge windows as to better reflect the actual behavior of the user. In the figure below a week schedule is shown where each charge window is set to conclude at 6 AM on weekdays (deadline for 100% charge). The green section would be the system suggesting the user to extend these periods until 07:50. This would mean that the system sees few or no drives before that time.

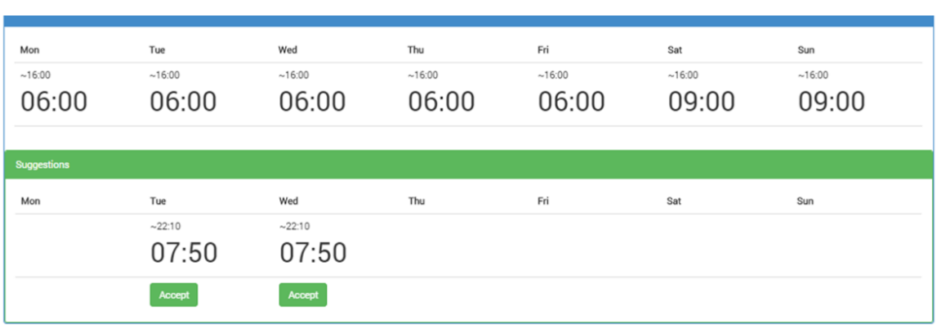


Figure 3- *Scheduled charge windows*

Functionality three: Spend and earned so far this month

This functionality is intended to address the economic and feel-good incentives of participating in managed charging. The user is presented with the accumulated economic and environmental savings achieved by participating in services.

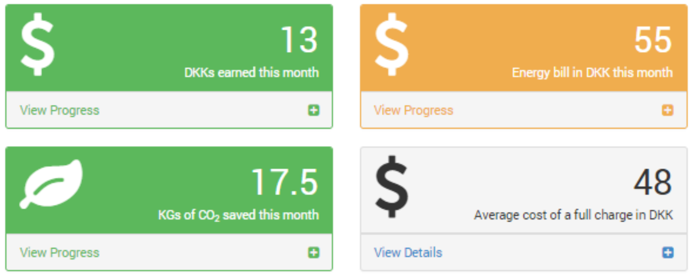


Figure 4- *Spent and earned so far this month*

Functionality four: subscribtions

The "subscriptions" functionality lets the EV owner control in which services the vehicle is to participate. Conveying the purpose and nature of the power and energy services to the EV owner is a challenge. Several services, such as frequency containment reserves and voltage support, can be difficult to understand for the end user. As such, it has been chosen to simply divide services into "Earning" and "Savings". Savings represents adaptive charging where charging is delayed in time to minimize the economical or environmental cost of charging. "Earnings" would then represent the more technical services where the EV actively supports the power system e.g. through frequent changes in active power.

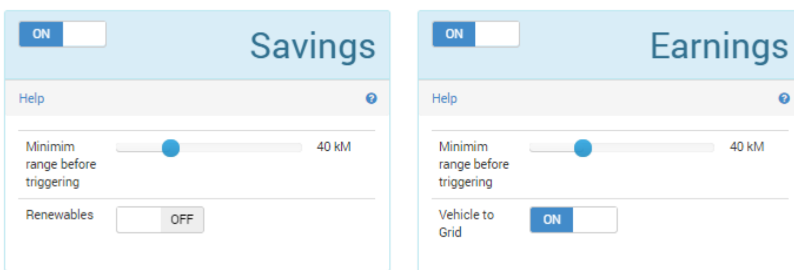


Figure 5- *Subscriptions*

User testing

To evaluate the value of the above functionalities, a user test was conducted with a small group of eight testers. These where primarily recruited through the test-an-ev trail described earlier. The test consisted of a web-based survey where testers used the above functionalities through a number of tasks. The survey was followed by an interview with each of the testers.

After using each of the functionalities, the testers were asked to rate how useful they found the functionalities. The following shows the results:

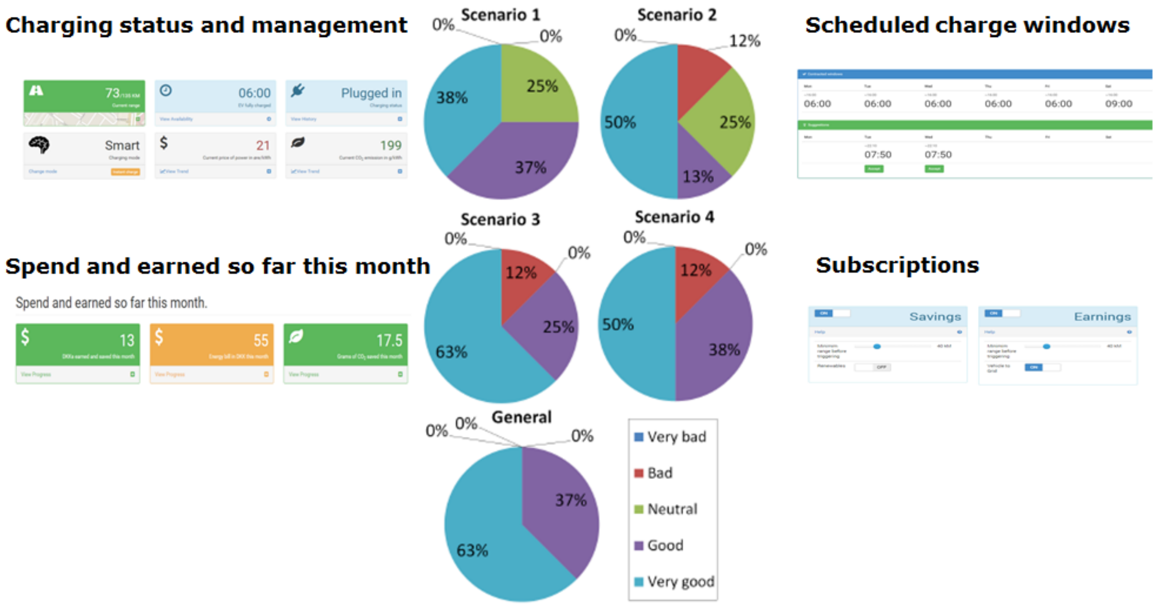


Figure 6- Evaluation of functionalities

The pie diagrams show the distribution of answers ranging from “very bad” to “very good”. It can be concluded that most testers found the functionalities useful. The small sample of testers doesn’t make it possible to conclude whether these functionalities will appeal to EV owners in general. Additional testing and development is necessary.

Besides from grading the usefulness of each functionality, the testers where also asked to provide comments and suggestions:

<u>Functionality 1: Charging status and management</u>

Testers generally found that the information presented would provide a useful overview of the current charging session.

“Information is clearly presented”; “frequent scenario”

<u>Functionality 2: Scheduled charge windows</u>

Testers generally found that the “charge windows” was a useful concept - but that it is important insure that user sufficiently understand the purpose of such windows. Also, the user should have an easy way of altering the charging windows.

“Charge windows are something you need to get accustomed to” “would love this feature” “Inform about why a suggestion is made” “cannot change or create new windows”

<u>Functionality 3: Spent and earned this months</u>

While the testers endorsed the functionality, there were many suggestions to how earnings and savings should be presented. There was also a wish for gamification – introducing targets and a competitive element to the feature.

“Interested in the energy bill and average cost” “price pr session” ”Average costs for a full charge doesn’t really matter””Gamificaton”

<u>Functionality 4: Subscriptions</u>

While the testers appreciated the simplicity of this functionality, there was also a wish for a bit more information on the difference between the savings and earning sections – and the impact that each choice entails (estimate of savings, impact on battery lifetime etc.).

"fear that my battery will degrade", "Earnings is a very interesting area", "a little more to spell out what is going on", "Yes, super easy!"

The user test has given a good initial idea of the usefulness of the functionalities and where improvements can be made.

Conclusion

The electric vehicle will only realize its potential as an asset to the power system if the owner is able and willing to let is play that role. If interfaces are made that emphasizes incentives, ease-of-use and user empowerment – this could increase users willingness to participate.

To better understand how user interfaces may support such willingness; the Nikola project has suggested four functionalities specific to the charging management. These functionalities has been implemented in a concept interface and tested by a small group of testers. The test has given the project a fist indication on the potential of such features. The main learnings of this effort are as follows:

- ✓ Having the vehicle participate in power and energy service will unavoidably delay the point in time where the vehicle will be fully charged. The EV owner should be able to cancel service participation for any session using a "Instant charge" feature.
- ✓ Analyzing charging patterns may be used to suggest suitable periods for service participation. I.e. recurring charging session which are long and predictable in nature.
- ✓ Explaining smart grid services to the user is a challenge and the right level of detail or abstraction should be found. The user may only wish to subscribe to a service if the implications are sufficiently understood.
- ✓ If the subscriptions describe WHAT the EV is allowed to do, the charge windows represent the WHEN. The user should know when the vehicle is scheduled to participate in services and a guarantee for when a fully charge vehicle will be available. Such deadlines can be suggested by the system – but must be accepted by the EV owner.

It is the intention to repeat the testing with a version 2.0 interface and a greater number of testers.

The enabling functionalities uncovered by Nikola will be made publicly available so that any technology company, tasked with developing interfaces for end users, may consider and implement these functionalities - ultimately supporting EV owners willingness to become active participants in EV power and energy services.

References

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